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EVALUATION OF THE OIL STORAGE CAPABILITIES OF SPR LEACHING STRATEGIES

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ABSTRACT

This report examines techniques for comparing the oil storage capabilities of selected leaching strategies for Strategic Petroleum Reserve caverns. In particular the area under the oil volume versus time curve is used as a measure for comparing options. The use of the techniques are illustrated by analyzing two cases. In one case five alternatives for leaching the 12 Phase II caverns at Bryan Mound are examined.' The other case examines two alternatives for developing the 490 MMB of oil storage planned for Phases II and III.

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Introduction

Even with the constraints imposed by brine disposal permits, construction schedules and site piping and pumping systems, there is still considerable flexibility in selecting leaching strategies for the SPR caverns. The techniques described in Leaching and Oil Fill Schedules for the Strategic Petroleum Reserve' are used to calculate leaching schedules of selected alternatives. The area under each oil volume versus time curve is then calculated. This area, the time of completion, and oil volume versus time curves themselves provide valuable measures in comparing the oil storage capabilities of the selected leaching strategies. As illustrations two cases are evaluated: varying the number of caverns in Groups 1 and 2 at Bryan Mound, and comparing two options for leaching Phases II and III of SPR.

Comparison Methods

The methods described in Reference 1 are used to calculate the oil volume versus time curves for the options being considered. The' leaching of the storage caverns is simulated using the SALT 77 computer code developed by Ahmad Saberian for the Solution Mining Research Institute. The idealized schedules that result from the computer simulation are converted into realistic schedules by including the effects of actual brine production rates, workover times, delays during sump development and contingency factors. A computer program has been written that will calculate a schedule for each cavern at a site (up to a total of 12). These individual schedules are then combined to give overall oil volume versus time for the site.

The simplest technique for comparing different strategies is by their completion dates. However, this is usually inadequate because the amount of oil storage prior to completion is ignored. Another approach is to compare the oil volume versus time curves subjectively. At times this is difficult because the strategies to be compared are such that decreased ability to store oil early in the leaching is accompanied by increased capacity later on or vice versa. In other words, the oil volume versus time curves cross one another. In such cases the areas under the oil volume curves can be used as quantitative measures. This "area" has the units of barrels-years and is a measure of the protection provided by the SPR program. Once a quantity of oil is placed in storage that quantity provides protection against the eventuality of import embargoes. The earlier the oil is placed in storage the longer it is available for providing protection. The integral of the oil volume curve of time includes both the oil volume and the time factors.

When this technique is used to compare two options, the time integrals of the oil volume curves must be computed on the same time intervals even if the options are not completed at the same time. Normally the integrals will be computed over a time interval equal to the longest completion time. For those options that are completed first, their oil volumes remain at capacity from their respective completion times to the end of the time interval selected for integration.

The area calculation can be made more sophisticated if the oil volume is weighted by a selected function of time. For instance, very early storage of oil in caverns being leached may be of little value because the existing ESR caverns may not have been filled to capacity. This situation can be handled by either including the ESR caverns in the evaluation of the options or by multiplying all oil additions made before the ESR caverns are filled by a weighting factor of zero. In another case, there may not be sufficient oil to meet world demands and continue filling SPR after a given date. This can be handled by multiplying all oil additions made after the given date by the probability that the oil will be available. This analysis approach is not attempted on the examples below because I have no basis for selecting the weighting functions.

First Example

The first example evaluates five options for leaching the 12 Phase II caverns at Bryan Mound. The baseline case assumes that the caverns are leached in two groups of six each. The leaching of the second group starts when the first group has been completed. The other four options consider the following groupings: a single group of 12, 7 in the first group and 5 in the second, 5 in the first and 7 in the second, and three groups of 4. The following assumptions were applied to all five options.

Start time: All caverns in the first group on day zero, all caverns of subsequent groups on completion of the prior group

Sump delay: 60 days for all groups.

Contingency: 10%

Brine production rate per cavern: 680 MB/D divided by number of caverns in the group.

Maximum oil delivery rate to the site: 240 MB/D

Leach strategy: Leach/fill with 58 days of workover time.

The areas under the maximum available oil storage volume curves from the start of leach and the total time required to reach capacity are given in Table 1. Another way of presenting the oil volume integral information is to calculate the number of days alternatives must be slipped or advanced relative to the baseline so that the areas under their oil volume curves match. As the start of a leaching alternative is advanced, the area under the curve will increase by an amount equal to the number days advanced times the maximum oil capacity. If the start of an alternative must be advanced a given number of days for its oil volume integral to equal the baseline, then the alternative is that many days behind the baseline. The times for the four alternatives in this example are given in Table 1.

The oil volume data are plotted in Figure 1 and given in Table 2. The data for the 12/0 and 4/4/4 options must be used with caution because their brine production rates (57 and 170 MB/D respectively) are outside the range of flow rates (85 through 136 MB/D) that have been modeled. This reduces the confidence in their oil volume curves. Also, the pumping system at Bryan Mound probably is incapable of achieving the 170 MB/D production rate needed for the 4/4/4 option.

Table 1 Comparison of the Five Alternatives for the Leaching of the Phase II Caverns at Bryan Mound

	12/0	7/5	(Baseline) 6/6	5/7	4/4/4
Area under oil volume* curve (MMB-yr)	301	350	344	335	326
Days ahead or (behind) baseline	(130)	18	-	(27)	(55)
Completion time (days)	1950	2140	2155	2165	2420

*Area computed over time interval 0 to 2464 days. Maximum available oil storage curve is assumed.

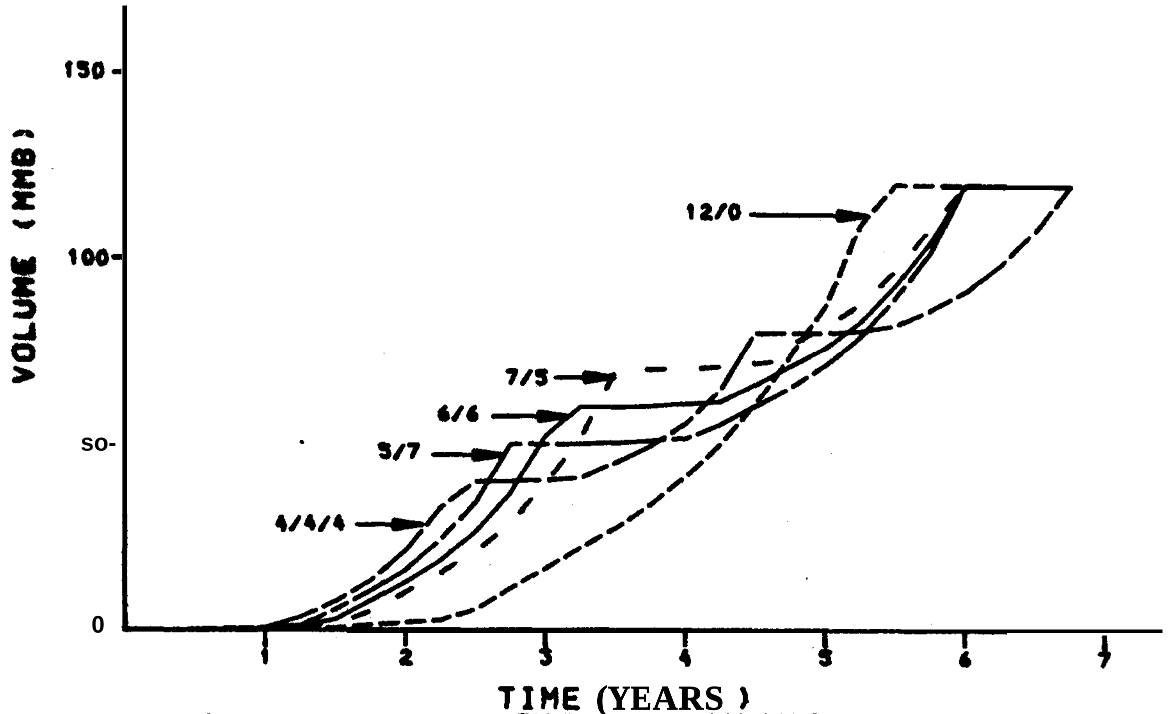

FIG 1 OIL VOLUME VERSUS TIME FOR FIVE GROUPINGS OF PHASE II CAVERNS AT BRYAN MOUND

Table 2 Oil Fill Schedules for the Five Alternatives for the Leaching of Phase II Caverns at Bryan Mound

Time* (years)	Baseline Oil** Volume (MMB) 6/6	Oil Volume Increment Alternative-Baseline (MMB) 12/0	7/5	5/7	4/4/4
l-l			0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0		0.2
a	0.5	-0.5	-0.2	0.1 0.1	0.2
2-l	1.1	-1.1	-0.2	0.1	2.3
2	2.9	-2.3	-1.4	2.7	4.9
3	7.8	-6.5	-2.8	2.6	5.3
4	12.8	-10.8	-2.7	3.2	8.5
3-l	18.5	-15.9	-3.3	5.1	14.3
2	26.5	-20.9	-5.4	7.9	13.5
3	36.9	-25.9	-9.2	13.1	3.1
4	52.3	-35.9	-12.9	-2.3	-11.9
4-l	60.0	-38.0	-0.7	-10.0	-19.1
2	60.0	-32.6	10.0	-9.1	-15.0
3	60.2	-26.6	9.0	-9.3	-10.0
4	60.8	-19.6	9.4	-9.3	-5.4
5-1	61.4	-11.6	9.4	-6.2	3.1
2	66.0	2.8	6.2	-5.7	14.0
3	11.0	11.2	5.9	-5.1	9.0
4	76.0		5.7	-4.7	4.0
6-l	83.0	26.1	4.9	-4.0	-2.4
2	93.0	27.0	4.0	-3.3	-10.9
3	104.7	15.3	3.8	-2.9	-16.2
4	120.0	0.0	0.0	0.0	-20.7
7-l	120.0	0.0	8:X	0.0	-21.4
2	120.0	0.0		0.0	-12.1

* The oil volumee apply to the end of the cited quarter, i.e., l-l is 90 days after the start of leach.
**Maximum available oil storage is assumed.

From Table 1 it is evident that the time required to complete the caverns is minimum for the 12/0 option and a maximum for 4/4/4 option. However, the level of protection against oil embargo as measured by the area under the oil volume curve is significantly less for the 12/0 option. This is because most of the oil for the 12/0 option is added late in the leaching schedule. The 7/5 option provides the best protection. However, the differences between the 7/5 and the 6/6 or the 5/7 are so small that they should be considered as equivalent. From Table 2 and Figure 1 it is evident that the 7/5 option has less oil storage capacity than the baseline option (6/6) during the first half of the schedule and greater capacity during the second half. The 5/7 option is just the opposite: more capacity during first half less during the second.

<u>Second Example</u>

The second example examines two options for creating the 490 MMB of oil storage that is planned for Phase II and III of SPR. The first option assumes that 49 ten MMB caverns are leached: 16 at Bryan Mound, 19 at West Hackberry and 14 at Big Hill. The second option eliminates the need for Big Hill by leaching 14 ten MMB caverns and 21 sixteen MMB caverns: 6 small ones and 10 large'ones at Bryan Mound, and 8 and 11 at West Hackberry.

The ten MMB caverns are the standard "flower pot" design capable of being cycled five times. The 16 MMB cavern was selected to match the volume and shape of a 10 MMB cavern that has been cycled five times. It has total leached volume of about 20 MMB and its shape is approximately a 270 foot in diameter by 2000 foot high cylinder. The major disadvantage of this larger cavern is that it cannot by cycled without reducing the web thickness between caverns to less than the established criterion. Time-volume **matricies** for the two caverns are given in Table 3. Both are based on a leach/fill strategy.

Table 3 Time-Volume **Matricies** for the Ten and Sixteen Oil Storage Caverns*

	Ten MMB Cavern			Sixteen MMB Cavern		
	Time (days)	Leached Volume (MMB)	Oil Volume (MMB)	Time (days)	Leached Volume (MMB)	Oil Volume (MMB)
Start	0	0	0	0	0	0
End of sump	160	2.6	0	160	2.6	0
End of roof	330	5.7	0.25	375	6.7	0.35
	530	9.3	2.6	730	13.2	3.8
	610	10.6	3.9	860	15.2	6.9
	665	11.4	5.2	980	17.5	9.9
End of leach	715	12.3	6.8	1160	20.0	12.8
Maximum oil capacity			10.0			16.3

*Assumed brine production rate is 136 MB/D.

In developing oil volume versus time curves for both options the parameters in Table 4 were assumed.

For option #1 all caverns were assumed to be ten MMB caverns. For option #2 the Group 2 caverns at Bryan Mound and West Hackberry were assumed to be sixteen MMB caverns, and the Big Hill caverns were not leached.

Table 4 Parameters Assumed in the Evaluation of the Phase II and III Oil Schedules

	Bryan Mound		West Hackberry		Big Hill
	Group 1	Group 2	Group 1	Group 2	
No. of caverns	6	10	8	11	14
Start time	2 on 3/10/80 4 on 7/20/80	5 on 1/12/83 5 on 5/23/83	8 on 5/1/81	11 on 10/28/84	14 on 10/1/85
Sump delay (days)	60	60	60	60	60
Contingency (percent)	10	10	10	10	10
Brine Prod. per Cavern (MB/D)	113	98	136	99	100
Max. oil delivery rate per Site (MB/D)	240	240	175	175	240

The options are compared in Table 5 and their oil volume versus time data are plotted in Figure 2 and given in Table 6. It is evident from Table 5 that the options are almost identical in

Table 5 Comparison of the Two Options for the Development of the Phase II and III Storage Caverns

	Option #1	Option #2
No. and size of caverns	49 @ 10 MMB	14 @ 10 MMB 21 @ 16.3 MMB
Area under oil volume curve (MMB-yr)	1690	1610
Completion Dates	5/16/89	4/19/89
Maximum Oil Storage (MMB)	490	482

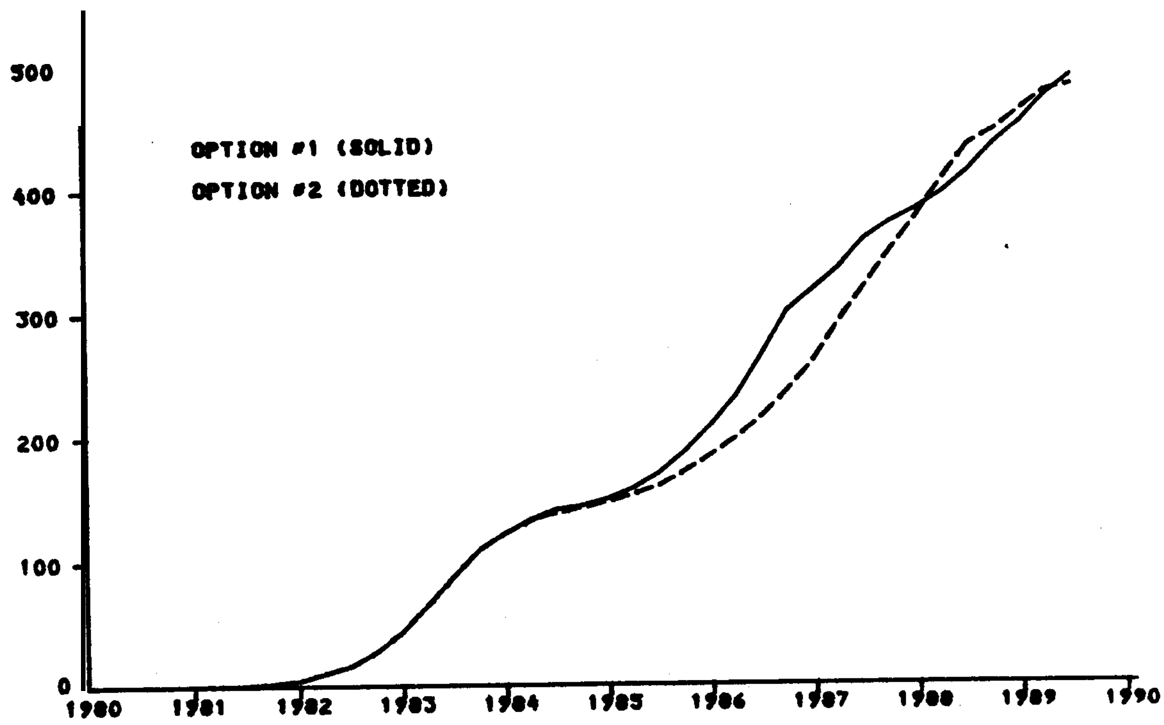

FIG 2 OIL VOLUME VERSUS TIME FOR TWO OPTIONS FOR THE PHASE II AND III DEVELOPMENT OF SPR

terms of their oil storage capability. For instance, the 80 MMB-yr difference in areas under the oil volume curves will vanish if the start of leaching at Big Hill slips by seven months.

Table 6 Oil Fill Schedules for Two Options for Phase II and III of SPR

Time (Years)*	Volume (MMB)** Option #1	Option #2
80-1	0.0	0.0
2	0.0	0.0
3	0.0	0.0
4	0.0	0.0
81-1	0.2	0.2
2	0.6	0.6
3	2.0	2.0
4	4.2	4.2
82-1	9.8	9.8
2	16.1	16.1
3	27.4	27.4
4	43.4	43.4
83-1	65.1	65.1
2	88.3	88.3
3	109.4	109.4
4	122.1	122.1.
84-1	138.5	i38.6
2	141.5	141.6
3	144.4	142.8
4	149.8	147.1
85-1	158.2	152.8
2	170.0	160.0
3	187.2	171.4
4	208.0	184.2
86-l	231.9	198.0
2	265.1	215.4
3	300.3	236.2
4	316.8	259.6
87-1	334.1	291.4
2	358.4	320.9
3	371.9	348.7
4	382.3	376.3
88-l	395.4	406.2
2	412.5	434.1
3	434.8	445.3
4	451.5	461.3
89-1	473.4	477.3
2	490.0	482.3

* The oil volumes apply to the end of the calendar year quarter.
**Maximum available oil storage is assumes.

The decision between the options cannot be based on their oil storage capabilities. The costs and uncertainties- of developing new complex at Big Hill must be weighed against the loss of cycling capability for most of the phase II and III storage. The decision to implement option 2 can be delayed until middle of 1984 with no impact on its final oil volume schedule. Therefore it can be kept as an alternative at no cost in the event that serious problems are encountered in developing Big Hill.

The two options discussed above are by no means the only options for Phase II and III development worthy of consideration. Examples of other options are as follows:

- All 35 caverns at Bryan Mound and West Hackberry can be leached to 14 MMB of oil capacity. These caverns would be capable of one and possibly two cycles, and they would hold a total of 490 MMB of oil.

- The caverns at Big Hill can be developed in conjunction with larger caverns at Bryan Mound and West Hackberry. This would yield partial cycling capability and a maximum capacity of greater than 490 MMB.

Conclusion

Leaching schedules for'creating SPR storage caverns can be derived using the techniques described in Ref. 1. Schedules derived under different assumptions such as different maximum oil. delivery rates or even different sizes can be combined into an overall schedule that gives the total leached volume, oil volume (minimum required and maximum allowed) and rates of oil delivery as functions, of time. Furthermore, the areas under the oil volume curves can be calculated to provide a measure of the protection provided by the options under consideration.

References

[1]H. C. Shefelbine, Leaching and Oil Fill Schedules for tahe Strategic Petroleum Reserve (SPR), SAND80-2784 (Albuquerque: Sandia National Laboratories, 1981).

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